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LOCATION OF THE MISSISSIPPI SOUND OYSTER REEFS AS RELATED TO SALINITY OF BOTTOM WATERS DURING 1973–1975[1]

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ABSTRACT The relationship of producing natural oyster reefs of Mississippi Sound to the salinity regime of bottom waters is investigated. Extreme and average conditions were extracted from data taken at 87 stations over a 21-month period from June 1973 through February 1975. With one exception, the producing reefs were subjected to salinity minimums of 2.0 to 4.0 parts per thousand (ppt), maximums of 18.0 to 22.0 ppt, with average conditions being between 10.0 and 16.0 ppt. Salinity-suitable areas in the Sound not now inhabited by oysters are described.

INTRODUCTION

Salinity plays an important role in the distribution, migration, growth and reproductive processes of most marine species (Pearse and Gunter 1957). The tolerance of the animals to normal fluctuations of salinity in the ambient waters depends largely upon the species' osmotic regulatory ability (Gunter et al. 1973). Thus, the absence or presence of salt in sufficient quantity constitutes a physiological barrier to most fresh, brackish or oceanic-water species. Motile forms, unless trapped, can usually avoid waters having salinity concentrations outside their tolerance levels. Less motile and sessile forms must employ other protective mechanisms or die.

The oyster *Crassostrea virginica* comprises the staple of the oyster fishery of Mississippi Sound and contiguous water bodies. The historically productive reefs of the Sound have evolved partly because of a satisfactory salinity regime. It appears reasonable that if the salinity regimes of the bottom waters over productive reefs were known, this information could be used to help identify other suitable areas for oyster cultivation. The objectives of this paper are to show the distribution of the average and extreme salinity levels observed in Mississippi Sound bottom waters over a 21-month period and to discuss the location of productive oyster reefs within this salinity regime. In Mississippi, where state law now permits the leasing of state water bottoms for the cultivation of oysters, site location relative to salinity will probably be a major factor in the outcome of the venture.

Crassostrea virginica is a brackish-water animal that can tolerate wide fluctuations in salinity; however, there are limits beyond which salinity must not go if the oyster is to remain alive, reproduce and "fatten" (Engle 1948). Gunter (1950) stated that oysters can survive a salinity as low as 2.0 ppt for about a month and can even survive in fresh water for several days. The experiments of Amemiya (1926) showed the upper and lower salinity limits of *C. virginica* to be 39.0 ppt and 1.5 ppt, respectively. In a series of experiments designed to determine the effects of salinity variations on oysters, Loosanoff and Smith (1949) found that fresh water conditions were not as detrimental to oysters acclimated to lower salinities as to those accustomed to higher salinity levels.

The influx of fresh water has been reported as a major cause of oyster mortality by many authorities: Ritter (1895), Cary (1906a, 1906b), Moore (1913), Galtsoff (1930, 1931), Lunz (1938), Viosca (1938), Engle (1946), Hopkins (1946), Gowanloch (1946), James (1946), Truitt (1946), Butler (1949, 1952), Gunter (1953), Beaven (1955) and Andrews et al. (1959). In addition, the oyster is prey to the conch *Thais haemastoma* especially when salinities rise above 12.0 ppt (Gagliano et al. 1970). Gunter (1950), referring to his unpublished experiments, stated that this predator dies at salinities between 10.0 and 8.0 ppt. The author, from personal observations over many years, can attest to the efficiency of *T. haemastoma* in the decimation of local reefs.

AREA DESCRIPTION

Mississippi Sound is a relatively shallow (3.05 m), elongate (128.3 km) body of water with an average width of 15.3 km. Its curvate major axis is aligned in approximately an east-west direction. The Sound is bounded on the north by the states of Mississippi and Alabama, on the east by Mobile Bay, on the west by Lake Borgne and on the seaward southern boundary by the Gulf of Mexico from which it is partly separated by a series of barrier islands. The distribution of bottom sediments has not been completely mapped for the area. However, charts prepared by Otvos (1976) show the existence of an irregular pattern of sediment types. The bottom types associated with oyster reefs in the Sound and bays are muddy fine sand and fine sandy mud. These same bottom types are also extensively present

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in areas not associated with oyster reefs. The producing oyster reefs of Mississippi Sound are shown in Figure 1 (Demoran 1977). The largest reefs lie south and southeast of St. Louis Bay, in Biloxi Bay and near the west mouth of Pascagoula River. Other smaller natural reefs scattered throughout the area do not appear on the chart. Since these reefs only occur in certain areas of the Sound in conjunction with the suitable sediment type, other controlling factors must exist.

The Sound receives fresh water from two major rivers (Pearl, Pascagoula), four minor rivers (Tchouticabouffa, Biloxi, Wolf and Jourdan), numerous tidal bayous and also by direct runoff. Of the minor rivers, the first two empty into upper Biloxi Bay while the latter two discharge into St. Louis Bay. In addition, the western end of the Sound eventually receives the drainage entering Lake Pontchartrain and Lake Borgne.

Only five previous investigations have addressed any aspect of the *in situ* oyster-salinity relationship in Mississippi Sound. Viosca (1938), assessing the effects of the 1937 opening of the Bonnet Carré Spillway on Mississippi Sound marine life, made some general observations. Engle (1948), in assessing the condition of reefs following the hurricane of 1947, noted a westward decline in salinity in Mississippi Sound. Butler (1949, 1952) looked at the effect of the flood of 1945 on local reefs. The study by Gunter (1953) dealt with the effect of lowered salinity on oyster reefs of Louisiana and Mississippi caused by the opening of the Bonnet Carré Spillway in 1950. In any case, the studies were limited to the effect of short-term changes in the salinity levels. Until recent years little was known of the general patterns of salinity in the Sound. Christmas and Eleuterius (1973) combined serially the monthly data and constructed bimonthly charts of salinity distribution for surface and bottom waters. However, these data were often widely separated in both space and time and were thus restricted to expressing general conditions. In 1973, a hydrographic study of Mississippi Sound was initiated. Eleuterius (1976) reported on the temporal and spacial salinity distribution of the Sound. Data on which this analysis is based are from the 1973 study.

METHODOLOGY

Eighty-seven hydrographic stations were established throughout the Mississippi Sound area (Figure 2). The numbering convention utilized was as follows: stations established initially were assigned an odd integer and stations added at a later time were assigned even integers. The number of stations and the vastness of the area precluded covering the entire Sound in a single cruise. The Sound was divided into three overlapping segments that can best be described by their east-west linear extents as follows: the eastern segment extended from the west tip of Dauphin Island to the east tip of Ship Island; the middle section covered the area from the west end of Horn Island to near the west end of Cat Island; and the western section extended from near the west end of Cat Island to just west of Half Moon Island. The three sections were overlapping in that stations on boundaries common to adjacent sections were occupied when cruises were conducted in either of the adjoining areas. Cruises were conducted approximately semimonthly in the eastern section from 14 June 1973 through 1 July 1974; in the middle section from 5 February 1974 through 25 February 1975; and in the western section from 1 March 1974 through 19 February 1975.

Conductivity measurements, later converted to salinity, were made by a temperature-compensated Martek, Model II system. The accuracy of the instrument in measuring conductivity is reportedly ±0.2 mmho/cm and less than ±0.1°C for temperature. The near-bottom measurements were always taken within 0.75-meter of the bottom.

For each station the minimum and maximum salinity levels encountered were determined and the average computed from the set of observations. Isohaline charts were constructed for each of the extremes and the average condition by employing linear interpolation to determine the path of the isopleths.

Only during a four-month period (February 1974 – May 1974) was sampling conducted simultaneously in all three sections of the Sound. By excluding this time period and comparing river flows (U.S. Department of the Interior 1973, 1974, 1975) of Pearl River located near the western end with Pascagoula River in the east, some clarification can be made of the vagaries of combining data offset in time from the different sections. For the period June 1973 through January 1974 when only the eastern section of the Sound was studied, the ratio of the flow of Pascagoula River to Pearl River was 0.94. When sampling was restricted to only the central and western sections (July 1974 through February 1975), the ratio of Pascagoula River to Pearl River flow became 1.1. Thus, there was a 16-percent change in flow relative to each other between the two time periods when sampling was done exclusively in the eastern and exclusively in the central and western sections. The western section probably experienced slightly higher salinities in the period when efforts were devoted to the eastern section as evidenced by the gauging point on Pearl River at Bogalusa, Louisiana, which showed an increase in flow of less than 0.5 percent over the earlier period. The Pascagoula River gauging station at Merrill, Mississippi, recorded an increased flow (17 percent) during the latter period over the earlier period of the study when sampling had been conducted in the eastern Sound.

Therefore, if sampling had taken place in all sections of

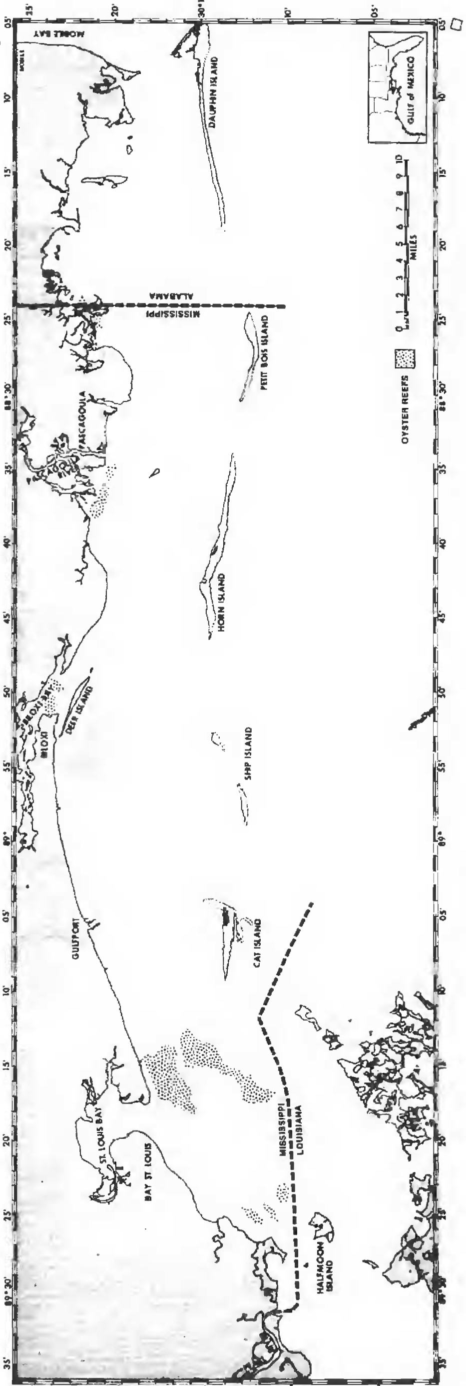

Figure 1. Location of productive natural oyster reefs, Mississippi Sound.

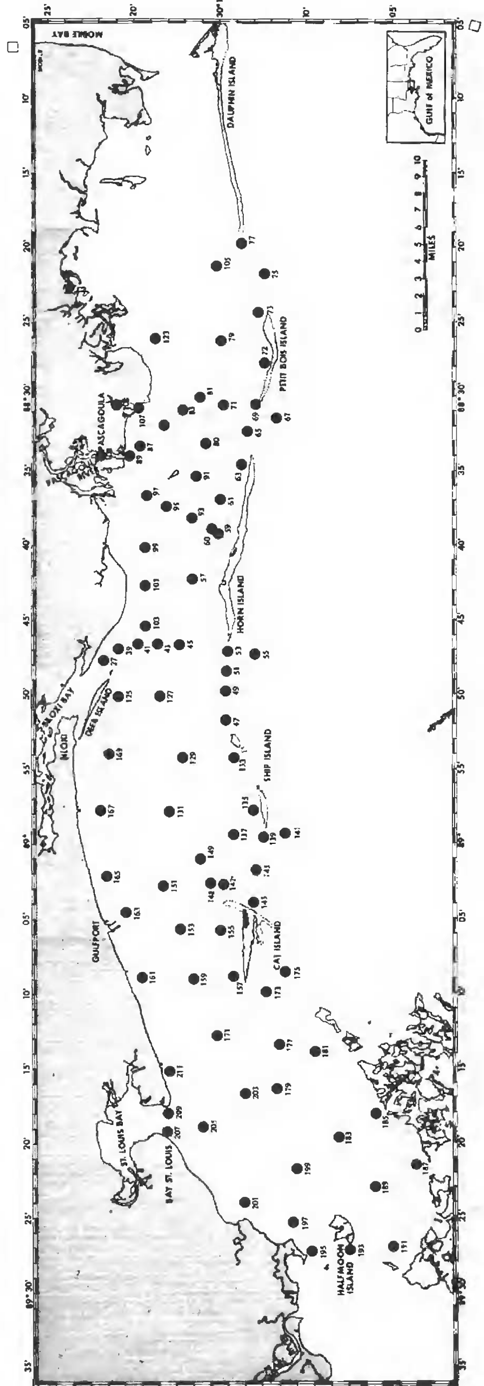

Figure 2. Station Locations, Mississippi Sound area.

the Sound for the entire period of June 1973 through February 1975, the combined data would have shown somewhat higher salinities in the western and central portions and lower salinities in the eastern portion. However, the peak fresh water flow of both rivers lasted less than two months in both years. Since sampling approximated a semimonthly effort and all measurements were given equal weight in the computation of averages, it is unlikely that any notable change would occur in the information presented here. While the salinity data analyzed here are based on a relatively short period of sampling, the general flow patterns implied by the configuration of isohalines are believed to be representative of the Sound waters. It should be pointed out here that the overall salinity of the Sound during this study appears lower than that observed in an earlier investigation (Christmas and Eleuterius 1973). However, since this paper is concerned primarily with relative salinity levels, this is of little importance here.

RESULTS AND DISCUSSION

The isohalines of the salinity-lows (Figure 3) clearly show the influence of the flow of higher salinity Gulf waters into Mississippi Sound through the island passes. The effect is manifested in the form of "tongues" that protrude into the Sound. The northeast-southwest orientation of the isopleths in the western end of the basin, while in this case depicting the lower extreme, is representative of the general pattern repeated in the individual cruises. The areal extent of the fresh water conditions in the western Sound are defined by the 2.0-ppt isohaline. The overall depressed salinity levels extend to the east beyond Cat Island. Therefore, all the major producing reefs experienced salinities between 2.0 and 4.0 ppt. The reefs near the mainland north of Halfmoon Island were probably subjected to almost fresh water.

The area of Mississippi Sound where the minimum levels were highest lies offshore between Gulfport and west Biloxi. Except for direct runoff, this area has no other nearby source of fresh water. The area west of the west mouth of Pascagoula River, known locally as Bellefontaine, is an extensive area that experiences depressed salinity levels attributable to the outflows of Pascagoula River and Biloxi Bay. Only a few scattered oysters exist in this area now. The discharge of the east branch of Pascagoula River mixes rapidly. Its reduced influence is noted by the observation that bottom water of 8.0 ppt never got farther than two miles from the mainland. Higher minimum salinity levels were found, as expected, in and near the ship channels.

Figure 4 depicts the distribution of the highest salinity levels recorded in the Sound's bottom waters. The northeast-southwest orientation of the isohalines again prevails in the western end of the basin. Special note should be made of the limited excursion of the 30.0-ppt water into the Sound through Cat Island Channel (between Cat Island and Louisiana marsh isles). The major oyster reefs south and southeast of St. Louis Bay were exposed to salinity highs between 18.0 and 22.0 ppt. The reefs north of Halfmoon Island did not experience salinities above 18.0 ppt. The area north of Ship Island and Dog Keys passes (between Ship and Horn Islands) is subject to salinities in excess of 30.0 ppt. The high salinities south of Pascagoula are all associated with the deep ship channel. With the exception of localized situations, the waters near the mainland from Gulfport eastward experienced salinity levels in excess of 26.0 ppt.

The distribution of average salinity levels for Mississippi Sound bottom waters is shown in Figure 5. The mean values are higher in or near the ship channels. The isohalines in the western Sound maintain their northeast-southwest orientation indicating that this is the normal pattern. The oyster reefs south and southeast of St. Louis Bay are situated in an area where the average bottom-water salinity is between 10.0 and 14.0 ppt. The average salinity on the reefs north of Halfmoon Island is 9.0 ppt. The mean salinity for Biloxi Bay in the vicinity of the major reefs lies between 14.0 and 16.0 ppt. In the area south of Bellefontaine, which is devoid of natural reefs, the average bottom-water salinity is between 14.0 and 18.0 ppt.

The location of producing oyster reefs in Mississippi Sound appears to be closely associated with a particular portion of the range in salinity. Except for those north of Halfmoon Island and those south and southwest of St. Louis Bay, most oyster reefs are located in bays or near the mainland. With the exception of those reefs north of Halfmoon Island, all of the oyster-producing areas experience similar conditions in salinity as to range and variability.

A previous study (Eleuterius 1976) of the spacial distribution of salinity and flow patterns of the Sound partly substantiated the claim of Engle (1948) that, in general, a decline in salinity exists westward through the Sound. The Pascagoula Ship Channel (depth > 12 m) permits the intrusion of higher-salinity Gulf water up the Pascagoula River where it mixes, thus reducing the fresh or very low-salinity water being discharged directly into the Sound except during periods of peak river flow.

A similar situation exists with the Gulfport Ship Channel which allows the excursion of higher-salinity waters into the Sound than would otherwise occur. However, the presence of this channel is probably of secondary importance to the maintenance of higher-salinity waters in the area, the primary reason for this being the absence of a substantial nearby source of fresh water.

Undiluted high-salinity Gulf waters are restricted from entering the western Sound. Waters exchanged through Cat Island Channel are almost exclusively the estuarine waters of Chandeleur and Mississippi Sounds. Furthermore, the

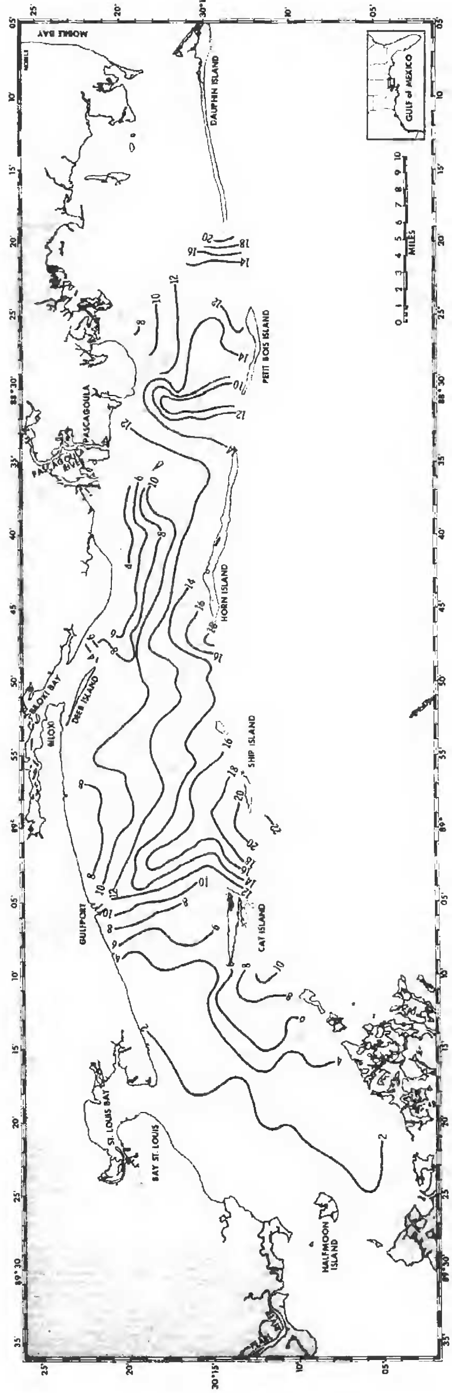

Figure 3. Distribution of minimum levels of salinity (ppt), Mississippi Sound, 1973–1975.

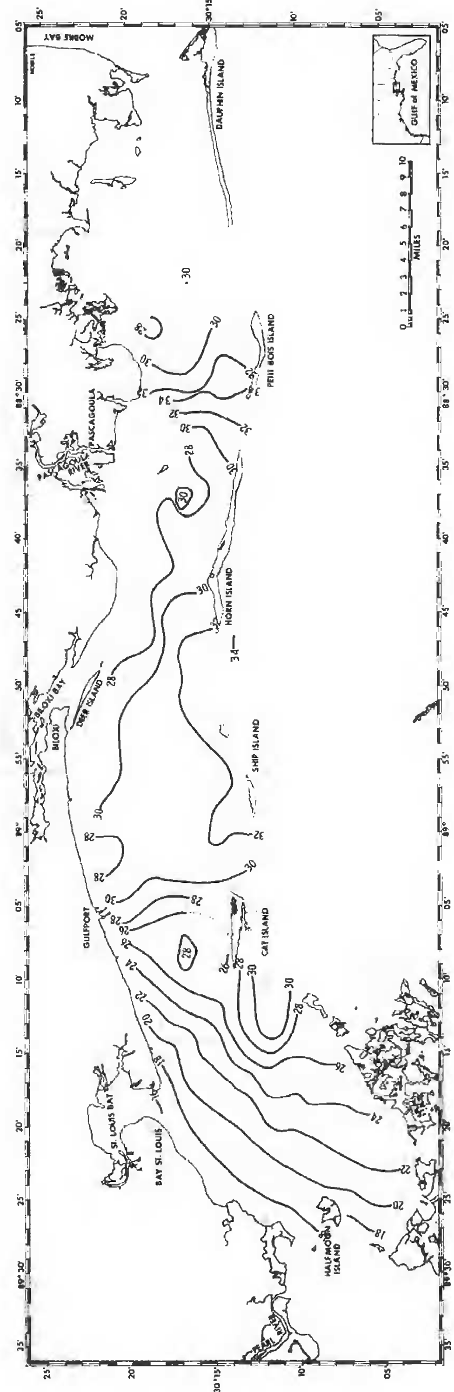

Figure 4. Distribution of maximum levels of salinity (ppt), Mississippi Sound, 1973-1975.

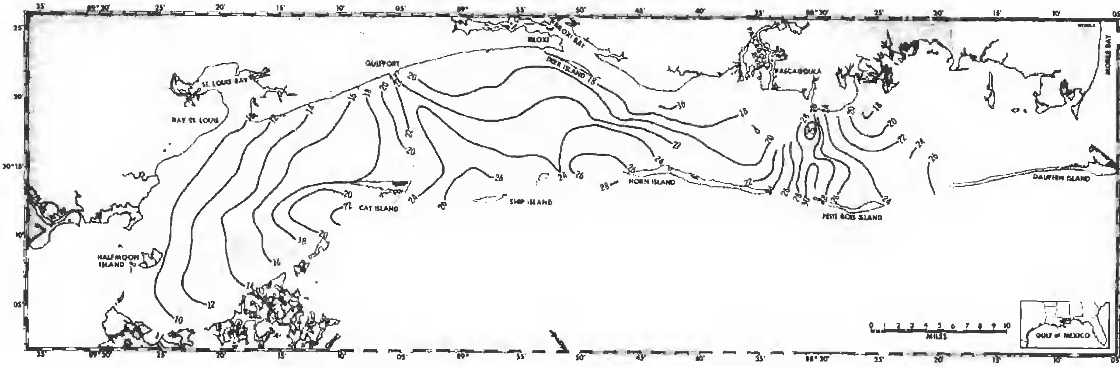

Figure 5. Distribution of average levels of salinity (ppt), Mississippi Sound, 1973–1975.

shallow shoals north of Cat Island Channel block the entry of denser, higher-salinity bottom waters. The combination of receiving the discharge of Pearl River, St. Louis Bay (Wolf and Jourdan Rivers) and Lake Borgne, plus the restricted communication with the open Gulf, is instrumental in maintaining the low-salinity bottom waters.

CONCLUSIONS

The productive oyster reefs of Mississippi Sound, from June 1973 through February 1975, were, in general, subject to salinity minimums of 2.0 to 4.0 ppt, maximums of 18.0 to 22.0 ppt, with average conditions over the reefs being between 10.0 and 16.0 ppt. These findings explain, at least in part, the location of the large reefs in the open area of the western Sound while productive reefs in the remainder of the Sound are found only in bays or very close to the mainland. These areas of the Sound are subject to similar salinity conditions. These remarks are not meant to imply that these specific salinity levels are either optimal or in themselves criteria that can be employed at any time to determine areas suitable for the cultivation of oysters. Rather, it is suggested that within the period of this study, these values could be used to identify areas with similar salinity regimes. While changes in fresh water input, and thus salinity, will occur from year to year, the pattern of flow of bottom waters will vary little. Suitable bottoms where oysters are now absent but have the same favorable salinity conditions as producing areas would seem to be the place where oysters could be successfully cultivated.

The western Sound, which is protected from high-salinity waters because of its limited communication with the open Gulf, shows the greatest potential for oyster cultivation. This region should be considered for future oyster cultivation based on the bottom-water salinity which lies between the 11.0- and 14.0-ppt isohalines of Figure 5. Because of normal low salinity plus the frequency of freshets, Butler (1949) recommended against cultivation of the far western Sound which lies west of these boundaries.

Because of the higher salinity of the central and eastern Sound, there are few areas outside of the existing reefs that appear suitable for oyster cultivation. However, one area that should receive serious consideration is south of Bellefontaine, and other possible sites lie just seaward of the tips of Deer Island. While there may be other areas that would be productive for short periods of time, eventually the oysters probably would succumb to the predator *Thais haemastoma* or, because of persistent low salinities, would not reproduce successfully. When used in conjunction with information on other factors affecting oysters such as bottom type and food supply, the information on the salinity regime of Mississippi Sound bottom waters should reduce the risk in the selection of sites for oyster cultivation.

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